Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

MINIMIZATION OF NOISE IN FOUNDRIES ON THE EXAMPLE OF THE IRON FOUNDRY IN BYDGOSZCZ

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Abstract

In this article, a negative impact of noise in foundries on both physical and mental abilities of the workers have been discussed on the basis of the authors own implementation solution. The result is work efficiency decrease and quality determination. On the example of Iron Foundry at PESA works in Bydgoszcz (former ZNTK). The effects of minimalization of the loudest noise sources in different departments of the factory have been presented along with the assessment of noise reduction effectiveness rate. The presented solutions can have applications in other casting foundries in the whole country.

Keywords: *noise in foundries and its minimalization*

1. Introduction

Protecting environment against all kinds of harmful factors, including noise, is a necessity of our times. Noise is one of the factors of the environment which in a significant way shapes living and working conditions of human beings. An obligation to evaluate the occupational risk related to the noise exposure and to reduce this risk to the lowest possible level taking into consideration technical progress and the possibility to reduce noise at its source is one of the main obligations of an employer. The above obligation results from the European legislation (Directive 86/188/EEC, Directive proposal 94/C230/03 and the project of a new Directive adopted in June 2002 by the EU Social Policy Council) and Polish legislation: Labour Code, Regulation of the Minister of Economy and Labour as of 5th August 2005 on occupational health and safety of work involving exposure to noise or mechanical vibrations.

One of the important problems is the noise in the work environment, especially at the foundries where the level of noise at the posts often exceeds permissible limits and the machines operating in this sector of the industry are one of the loudest. On one hand, they create difficulties for the employees operating them (fatigue, risk of hearing loss, reduction of speech intelligibility and perception of signals), on the other hand, the noise created by these machines and emitted through the openings of the buildings and warehouses is usually sensed in the neighbourhood as very disruptive [2,4].

Progress in recognizing the dependencies between the influence of noise and health condition of an employee and their psychomotor features should contribute to undertaking more and more effective projects in the field of protection against noise. The main direction of activities related to noise should be fighting against noise on the legal, technical and organizational level. This is not the task to be achieved in near future since it involves spending large amounts of money e.g. for construction of noise protections already at the stage of designing and operating noisy equipment (machine). On the other hand, failure to undertake protective actions causes huge losses difficult to be measured directly or even immeasurable [1,2,5].

The article presents the analysis of the problem related to the industrial noise at foundries and the possibilities of its minimization illustrated with an example of Bydgoszcz Iron Foundry at PESA Plant (formerly ZNTK) in Bydgoszcz.

2. Negative influence of the industrial noise on the employees of a foundry and its effects

According to the estimates presented by the National Labour Inspectorate [3,5], noise in the foundry industry is one of the biggest industrial dangers and it constitutes 45% of all dangers. In the second place is dust 25% and subsequently toxic compounds 6%, vibrations 7% while the remaining 25% are factors of the work environment (mechanical dangers, lighting, microclimate, biological pollution, electromagnetic fields etc.).

Machinery and equipment used in the foundry industry are the loudest of all industry sectors and these are: jolt moulding machines, shake-out grids, tumbling barrels, conveyor systems, ventilation systems, forming machines, compressed air dischargers, grinding machines etc. The average sound level for this group of machines is 90 to 125 dB(A) [1,6,7,9, 10].

Therefore the noise at foundries is a danger of the work environment which exceeds the permissible limits the most often. Its presence, which has been proved [2,5,7], contributes to the high number of accidents and injuries, sickness absences (also not related to accidents) and, what is the most important economically, to low productivity and poor quality of work.

The losses incurred by the management of foundries, insurance companies and health care centres as a result of occupational diseases, accidents and injuries are relatively significant, but the losses related to the fact that people working in a noisy environment will do less, worse and will damage more castings are at least ten times bigger [5,8,11].

Harmfulness and onerousness of the noise at foundries depend on its physical features and on parameters such as: sound level, frequency, spectral characteristics, nature and time ranges of acoustic vibrations as well as on the relation between the machine operator and the source of the noise.

Table 1 shows that the harmful influence of acoustic vibrations related to the noise at foundries can affect health and when it comes to the productivity and work quality at foundries it can also have functional effects [2,5 10].

Health effects are: a psychomotor performance of an employee, their mental (emotional) state, their mood and health, quality of hearing and their diseases. Functional effects which influence productivity and work quality are: lack of independence, insecurity, loss of orientation in the environment, lack of comfort and understanding.

Figure 1 presents health and functional aspects during work of employees of foundry industry [3,9].

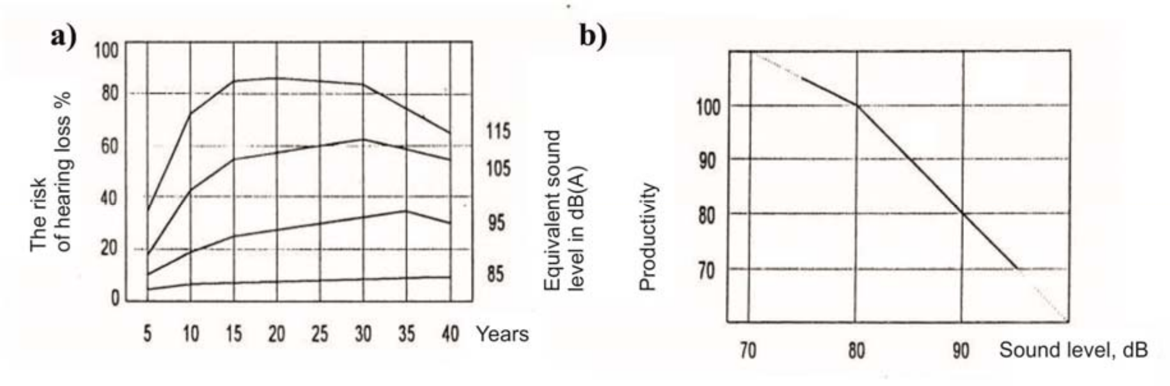

Fig. 1. Effects: a) on health; b) on the people's work effectiveness in the casting industry depending on the noise level

Tab. 1. Impact of noise on the employees health and work efficiency

Ref. no.	Equivalent sound A level (dB)	Impact on a human being
1	up to 35 dB	Harmless but irritating
2	from 35 to 75 dB	Exhausts nervous system, lowers productivity, influences speech intelligibility, reduces the effectiveness of perception, difficulties with concentration
3	from 75 to 85 dB	Makes it difficult to sleep and rest, longer exposure causes headaches and has negative influence on nervous system, it causes hearing impairment, makes remembering difficult, reduces the efficiency of the process of thinking and reasoning
4	from 85 to 130 dB	It causes permanent hearing damage, disorders of cardiovascular, nervous and balance system, makes speech intelligibility from a distance of 0,5m impossible, reduces the efficiency of solving problems, increases sensitivity to confounding factors
5	over 130 dB to 150 dB	It stimulates vibration of some internal organs of a human body and causes their chronic diseases and sometimes complete destruction of internal organs of a human being.

To estimate financial effects achieved thanks to reducing the noise we can use the notion of the so called effectiveness of noise reduction which is described by the formula [5]:

$$E = \frac{M \cdot \Delta L}{\Delta C} \tag{1}$$

where:

E – the effectiveness of noise reduction in the object, in dB (A) x person/1000 PLN or average gross salary,

M – the number of people for whom the noise has been reduced,
ΔL – estimated or actual value of noise reduction, in dB(A) reaching the above-mentioned group of people,
ΔC – the costs of the noise reduction, PLN.

The higher the value of effectiveness E is, the better the results of the implemented solutions reducing the noise attributable to one person exposed to the above-average sound level are.

It is estimated that [2,5,9] the reduction of noise at foundries by only 1dB(A) gives an average increase in productivity by 1,5%, reduces the number of deficiencies, accidents and injuries by 10%, reduces sickness absences not related to accidents by 4% and generally reduces the risk of occupational hearing loss.

3. Examples of the noise minimization at Bydgoszcz iron foundry

Below you can see examples of the noise minimization at Bydgoszcz Iron Foundry at PESA Rail Plant (formerly ZNTK) in Bydgoszcz, introduced in 1999 [12]. Bydgoszcz Iron Foundry casts brake pads from grey iron with the addition of phosphorus.

The sound levels of the main noise sources located in different Divisions of the Foundry are presented in Table 2.

The analysis of the noise sources shows that the sound level at different divisions and posts is significant and sometimes very high, exceeding the permissible limits and reaching up to 115 dB(a). Spectra of the main noise sources in octave bands of 63÷8000 Hz center frequency were also identified by making at each point of the post from 4 to 15 detailed measurements.

The results of the research were used to develop soundproofing constructions and to select appropriate absorbing and insulating materials for sound-absorbing structures for particular noise sources (Table 2).

The reduction of the noise of OPB tumbling barrel (point I, Table 2) used for cleaning brake pads of total length 9m and diameter of 2,5m was difficult to achieve. This noise decided about its output value on the conveyor belt 67 placed outside the room in which the barrel was placed. An important issue was to reduce the energy caused by hitting of the finished castings against metal resonant cavity of the barrel. It was soundproofed by putting another sound-absorbing and insulating layers on the body of the barrel using channel sections to connect them [50 according to Fig. 2.

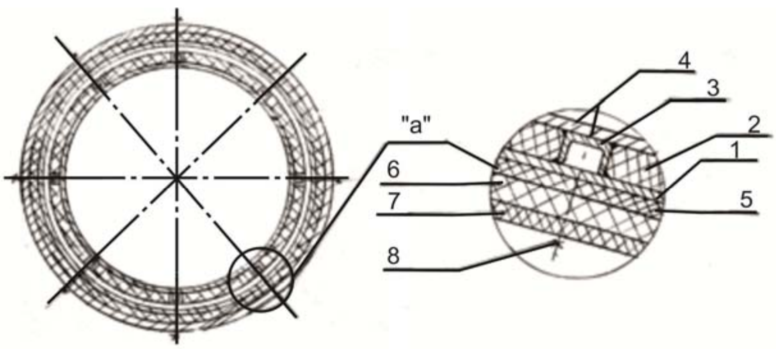

Fig. 2. Silencing the tumbling barrel noise: 1 - the barrel outer coat; 2 - mineral wool layer; 3 - fastening channel; 4 - inner coat; 5 - inner gum coat; 6 - mineral wool layer; 7 - outer gum coat; 8 - a screw with spring washers connecting gum coats with the main body

What is more, insulation of the walls of the room where a tumbling barrel was placed was reinforced by putting soundproofing curtains made of rubber coats and thick canvas on the walls.

For the reduction of noise of metal conveyor systems and of dropping of castings, scrap-metal and coke to cupola (point II, III, V, XIII, XV, Tab. 2) hard rubber ≠10mm was used which not only reduced material vibrations of the dropped mass caused by the impact, movement and friction of the transported castings (charge material), but also served as a great protection for a metal load-bearing construction of the transporting and dropping equipment before expenditure which is presented in Fig. 3.

The reduction of noise in the pipeline systems transporting heated air from the heaters to cupolas (point XIV, Tab. 2) and at the production halls of the foundry adjacent to the station was achieved thanks to the increase of attenuation of pipeline channels (the use of absorption silencers), stiffening pipelines and acoustic adaptation of the hall where heaters are placed (hanging appropriately selected spatial cone-shaped absorbers and wall insulation), but also thanks to placing the heaters on the soundproof rubber plates.

Tab. 2. Effectiveness results of noise minimalization solutions applied in the Foundry in Bydgoszcz

Ref. No.	Source of the noise	Average sound level before soundproofing L_1, dB(A)	Average sound level after soundproofing L_2, dB(A)	Effects of soundproofing $\Delta dB = L_1 - L_2$	Runtime of a device per shift in hours	Estimated equivalent sound level L_{eq2} dB(A) (after soundproofing)	Equivalent sound level according to the norm L_{eq}, dB(A)	The variation from the norm, dB(A)	Effectiveness of soundproofing, E# $\left[\frac{person * dB(A)}{PLN}\right]$
1	I – tumbling barrel	114,9	103,8	11,1	5	100,2	87	-13,2	2,21
2	II – receipt of insertions, belt 67	103,8	92,0	11,8	5	88,3	87	-1,3	2,84
3	III – chute 67/68	98,7	92,3	6,4	4	87,8	88	-0,2	1,76
4	V – chute 64/65	107,5	95,1	12,4	4	93,8	88	-5,8	3,32
5	VI – DISAMATIC A	88,2	82,8	5,4	4	80,5	88	7,5	1,63
6	VII – DISAMATIC B	87,5	82,1	5,4	4	80,5	88	7,5	1,63
7	XIII - gantry	105,7	88,2	21,6	2	84,5	94	9,5	3,81
8	XIV – turbo blowers	99,2	84,1	15,1	8	83,5	85	1,5	3,46
9	XV – coke loading	87,4	80,5	6,9	1	81,5	94	12,5	1,95
								$E_{śr}$	2,51

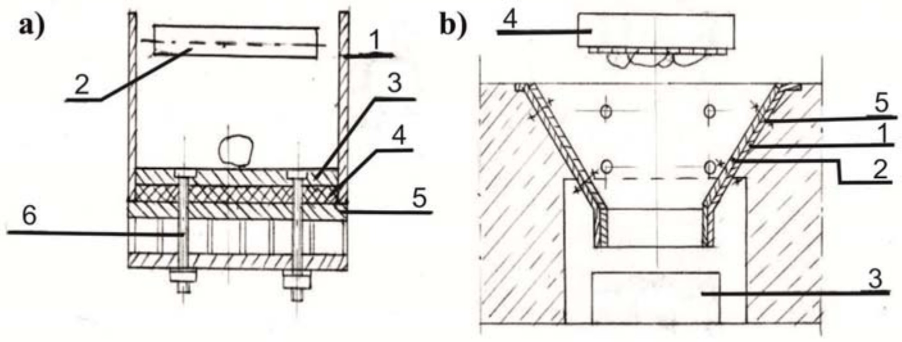

Fig. 3. Silencing scheme of shutes
a) transport shute: 1 - shute silenced; 2 - transport series; 3 - upper steel board; 4 - lower gum board; 5 - lower steel board; 6 - fastening screws with spring washers
b) charging hopper: 1 - metal housing; 2 - gum boards; 3 - receiver device; 4 - electromagnets; 5 - fastening screws with spring washers

Pneumatic (aerodynamic) noise caused by a sudden exhaust of the compressed air into the atmosphere from the control system of the machine used to form brake pads of two lines DISAMATICA A and B (points VI, VII, Tab. 2) was reduced by directing the exhaust air using appropriately selected (of a specific length and section) wires into the inner space of the body of the forming machine bearing and by using several individual expansion silencers with small measurements which is presented in Fig. 4.

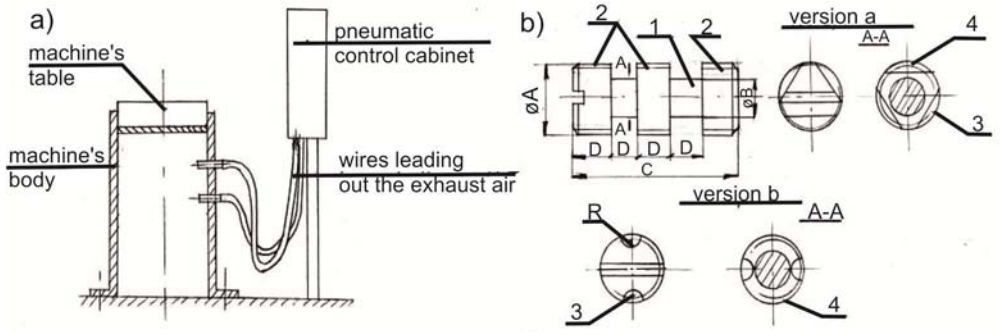

Fig. 4. Pneumatic noise silencing of the DISAMATIC line:
a) directing the air flow into the space of the body
b) small expand silencers: 1 - cylindrical bolt; 2 - gummed collar; 3 - prismatic or grooved cuts

After substantial soundproofing the devices minimizing the noise were subject to practical verification in the production environment in terms of mechanical durability, resistance to attrition (transporting and dropping equipment) and cracking caused by impact loading for the period of 2 years. It was found that too high temperature of brake pads coming out of the barrel and production line destroyed after around 1 year the hard rubber. Therefore, even harder, easily replaceable vibroacoustic plates were used.

4. Evaluation of the achieved effects

After introduction of the devices minimizing the noise the measurements were made at the same points as initial measurements. At each point several series of measurements were conducted. The purpose of such detailed measurements was to determine total acoustic effect of soundproofing works as well as to objectively determine the equivalent sound level at the posts and in the places where the employees exposed to noise spend time.

To estimate the equivalent sound level at the post L_{eq2} (after soundproofing) the norms PN-EN ISO 3744, PN-EN ISO 3746, PN-EN ISO 11201 were used including runtime (technological time) of the devices at the foundry during one shift and compared it with the standardized equivalent sound level L_{eq} (PN-ISO-01307) which is presented in Table 2. Table 2 presents also the values of effectiveness of noise reduction E calculated using the formula (1) at particular Foundry Divisions.

The results presented in Table 2 show that high acoustic effectiveness of the devices minimizing the noise installed at the Iron Foundry was achieved. There was a great decrease of the noise at particular points: at point II (belt 67), where employees are most exposed to the noise, it decreased by around 12 dB(A), at other points by average 5÷8 dB(A) and at some points even by 15÷20 dB(A). The achieved average rate of effectiveness E=2,51 is also high. It means that by spending on soundproofing 1000 PLN per employee of the foundry working in a noisy environment (exposed to noise) we receive the noise reduction of around 2,5 dB(A) which means that the energy of the noise reaching an employee is two times lower [5,11].

5. Summary

Although high acoustic effectiveness was achieved some of the achieved results did not meet the requirements of the PN-ISO-01307 norm, this applies especially to point I (tumbling barrel), IV (chute 64/65) and to some extent to point II (belt 67). The noise exceeds the limit at these points by around 13÷1,3 dB(A) (Table 2).

Further soundproofing of these points is possible by, for example, increasing insulation and acoustic absorption of the post at the belt and its surroundings, by hanging appropriately selected absorbing and insulating structures and additionally by covering the inner part of a steel coat of a tumbling barrel with very hard rubber (resistant to high temperatures).

However, besides the effects strictly acoustic achieved at the foundry we should not overestimate related to this decrease functional effects.

The increase of the quantitative effect of work (productivity and work quality) at particular posts at the foundry while decreasing sound level by 5 dB(A) in appropriate time ranges will amount to [5]:

- from 100 dB(A) to 95 dB(A) ~10%
- from 95 dB(A) to 90 dB(A) ~7%
- from 90 dB(A) to 85 dB(A) ~6%
- from 85 dB(A) to 70 dB(A) ~ 10,5%

Together it can give an estimated increase in productivity up to around 23%.

The influence of noise reduction on the number of accidents, injuries and sickness absences not related to accidents as well as on the number of cases of occupational deafness can be estimated as even greater i.e. by reducing the noise by 5 dB(A) [5] the number of accidents and injuries should decrease approximately to: $(1 \div 10\%) \cdot (1 \div 10\%) \cdot (1 \div 10\%) \cdot (1 \div 10\%) \cdot (1 \div 10\%) = 0{,}9^5 = 0{,}59 \approx 60\%$ of the previous number of accidents and injuries while reducing the noise by 10 dB(A) can decrease their number to $0{,}9^{10} = 0{,}35 \approx 35\%$ which means around 1/3 of their number before soundproofing.

A significant decrease of sickness absences not related to accidents at the foundry while reducing the noise by 5 dB(A) can be estimated as the value equal: $(1 \div 4\%) \cdot (1 \div 4\%) \cdot (1 \div 4\%) \cdot (1 \div 4\%) \cdot (1 \div 4\%) = 0{,}96^5 = 0{,}82 \approx 82\%$ of the sickness absences before soundproofing while reducing the noise by 10 dB(A) as the value equal $0{,}96^{10}=0{,}66 \approx 66\%$ of the initial sickness absences at the foundry which means by 1/3. Observations of the management of the foundry made over a long period of time (around 3 years after implementation) confirmed the above estimations and proved practical increase in productivity and work quality and decrease of the accident rate within 10% at the discussed Foundry.

From the presented above results and facts it can be concluded that the noise at the posts in the foundry industry affects health and availability of employees causing lower and poorer effects of work regardless of their will.

As we can see there are important economical, medical and ecological reasons why the noise in the foundry industry should be reduced.

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